Acquisition of Cryogenic Testbed for Electronic Evaluation of Materials in the Detector Systems Branch, NASA GSFC Code 553

Overview / Background:

The Detector Systems Branch of NASA Goddard Space Flight Center requires a rapid-cycle cryogenic testbed capable of achieving ultralow temperatures. This project is undertaken in support of NASA's mission to build detectors and detector system components with high yield and optimized performance. The best detectors and detector systems often require cooled components and the best detector performance can be achieved at ultralow temperatures. The fabrication of these components requires knowledge of the properties of the materials in the detector components at the operation temperature intended for the detector system. To achieve NASA's objective of enhancing throughput of successful detector components and enabling characterization of a wider range of materials properties, the project aims to acquire a cryogenic testbed with simple operation that achieves low temperatures quickly. Additionally, NASA seeks to eliminate the use of liquid cryogens in achieving ultralow temperatures. Liquid cryogens are an expensive consumable with high overhead costs for labor and safety requirements when the liquids are used in NASA laboratories.

To support its detector programs, NASA requires a rapid-cycle, high-fidelity testbed for measuring electrical properties of materials over a wide range of low temperatures. Ideally, this test platform will be designed to give access to the 0.05 K to 4 K temperature range within 24 hours of mounting samples in the system. The system in its testing configuration will achieve a base temperature of 50 mK with no heat load (except testbed wiring and thermometry) and will maintain temperatures below 100 mK for 24 hours with a microwatt heatload. The system must provide both sufficient cooling power and a suitable electromagnetic environment for measuring electrical properties of superconducting and resistive samples. The system should operate without use of liquid cryogens for cooling or precooling of the system or its components. The system should be built for robustness, with the expectation that it will perform within specifications for temperature and temperature control over an extended period with limited or no maintenance. The system should be designed with a rapid duty cycle (warm for sample loading to cryogenic temperatures and back to warm) such that several cooldowns can be conducted in a work week to support the rate of work anticipated for the system once installed at GSFC.

Objectives:

Under this agreement, NASA GSFC will obtain a refrigeration system that cools to a 50 mK base temperature and remain below 100 mK for 24 hours under a nominal heatload without the use of liquid cryogens (such as liquid nitrogen or liquid helium).

The system will be capable of rapid turnaround testing of electrical properties of materials in an environment free of contaminating electromagnetic or mechanical sources.

The system performance will be demonstrated by the vendor at NASA GSFC prior to acceptance by the GSFC technical representative.

Scope:

This agreement pertains to the design and construction of a cryogen-free refrigeration system by a vendor for delivery and performance verification at NASA GSFC. The statement of work describes the specifications required for the system to be delivered to NASA GSFC. It also describes the required interface between the vendor and the technical representative at GSFC for design approval and payment of the vendor by GSFC including milestones and schedule.

Specifications (Tasks and Requirements):

Here we list the requirements assuming the vendor proposes to build an Adiabatic Demagnetization Refrigerator (ADR) to meet the specifications. Alternative systems, such as a Dilution Refrigerator (DR) may be proposed, particularly if the specifications listed below can be met or exceeded in a cost effective manner.

Vacuum Dewar

Refrigeration system will be provided in a leak-tight vacuum dewar of rugged construction

Dewar will have built in attachments for mating with a dewar stand that can support the full weight of the dewar.

Dewar should fit within a cylinder 3' in height and 2' in diameter

Vacuum seals will be o-ring (e.g., viton) for uncooled interfaces such that ports and the vacuum jacket can be disassembled and reassembled easily without compromising the vacuum base pressure. Indium seals will be used on cooled interfaces.

The dewar will provide a pumping port for each volume that needs to be evacuated with a quick-disconnect o-ring flange. Flanges will have leak tight caps, fasteners, and o-ring assembly.

The dewar will have internal radiation shields at each temperature stage installed in the system.

Mechanical tolerances in the radiation shield design will be chosen to suppress radiation leakage from the warmer temperature stages into the colder stages.

Other radiation suppression (e.g., baffles, black paint on surfaces) will be described in detail.

The vacuum dewar will provide leak-tight access ports into the vacuum space including unused ports that can be customized by the user. The vendor proposal will describe the use of each port into the system and provide suitable baffling and/or radiation suppression for the radiated heat from the room temperature port and its contents.

The vacuum ports must use standard KF fittings. There must be at least three blank ports with KF fittings for customizable interfaces for the customer to use.

The vacuum dewar will be designed to provide straightforward access to each temperature stage in the system. Temperature stages will have unused attachment points and room for user customization (for example, for wiring heatsinks)

The system will have a remote valve for the cryocooler to reduce EMI from the compressor

There must be an accessible stage of cooling below 1K for cooling wires that will be connected to electronics at 3K and the detectors at the base temperature.

The system must include a power supply to energize (i.e., supply current to) the magnet.

The system must include the capability to regulate the temperature of the base temperature stage by controlling the current in the magnet.

There must be radiation shields at the 1st stage (< 50K) temperature of the cryocooler.

There must be a radiation shield at the 2nd stage (< 3K) temperature of the cryocooler.

Space for wiring & connectors - There must be enough penetrations through the 1st radiation shield for wiring so that at least 7 micro-D connectors can be mounted. Each micro-D connector will contain 25 connections. The penetrations needed for the thermometry are not included in this count.

Space for wiring & connectors - There must be enough penetrations through the 2nd radiation shield for wiring so that at least 3 micro-D connectors can be mounted. Each micro-D connector will contain 25 connections.

It is possible that some of the space reserved for micro-D connectors will instead be used for low temperature coaxial cable. But a similar area on each temperature stage is required.

There must be an area of at 2 x 2 sq inches on the 2nd stage (3 K) that is unoccupied and can be used to mount printed circuit boards for superconducting electronics.

There must be suitable scheme for mounting wiring to the sub-1K cooling stage.

There must be a suitable area for mounting devices to the base temperature stage.

The volume of work space that is enclosed by the 2nd stage radiation shield must be large enough so that a 1" x 1" x 5" volume of copper can be mounted at the base temperature stage.

The volume of workspace at the lowest temperatures should also have suitable room to accommodate up to 100 twisted pairs of wires (typical length 10 cm; typical diameter .003")

Cryogen Free Operation

The system will be supplied with a mechanical cooler and separate compressor unit for operation of the cooler.

The mechanical cooler will provide at least 0.7 W of cooling power at 4.2 K

Design of attachment of mechanical cooler to the system will include vibration damping and thermal attachments to various temperature stages in cryostat such that the vibrations from the mechanical cooler are decoupled from the cold stages internal to the cryostat. (In addition to the coldest stage – which would warm up from the vibrations, the other temperature stages should also be decoupled to prevent coupling of vibrations into the sample and thermometry wiring).

Refrigeration Design / Performance

Here the operation and design of the refrigerator should be described to give the technical reader insight into why the design will be successful in meeting the specifications

The operating principle and materials used in the adiabatic demagnetization refrigerator (ADR) should be described (e.g.., GGG and FAA crystalline salts)

The design of heat conduction from ADR materials into cooling surfaces should be described

The design of the interface from the refrigerator to the customer package and shields should be described at each temperature stage.

Vendor will estimate the magnitude of the residual magnetic field at testing space during routine operation (the first 24 hours after demagnetization)

Vendor will provide a description of magnetic shielding materials and dimensions, including a calculation of the magnetic field attenuation in their shield design.

If another refrigerator design (other than ADR) is proposed, the vendor will include a cost-benefit analysis as to how the competing design is effective for NASA compared to the ADR design

The refrigerator unit must be capable of obtaining a base temperature 50 mK and maintaining a temperature below 100 mK in excess of 1 day (24 hours) per cooling cycle without a heat load

Temperature stability of the system operated below 100 mK will be less that 20 microKelvin rms when operated in a feedback controlled loop. When operating open loop, the system base temperature will drift at under 1 mK/min

Vendor will describe the mechanical heatswitch design. Passive heatswitches such as gas-gap heatswitches will not be accepted.

Vendor will describe the kinematic suspension of the salt crystals including tolerances for maintaining thermal-mechanical design so that the suspension tensions upon cooling.

Thermometry

Vendor will supply calibrated sensors suitable heatsunk for readout at coldest temperatures from .05 to 4 K

Vendor will supply diagnostic thermometers for all other temperature stages and the temperature of the magnet and/or the magnet shield

Vendor will supply an interface with lowest temperature stage thermal control such that the temperature can be controlled with the magnet current.

Vendor will supply electronics for the readout of all thermometry at bias currents that avoid thermometer self heating or excess power dissipation in the cryostat.

Vendor will supply electronics for readout of current supplied to magnet and a conversion for that current into magnetic field in the magnet.

Vendor will supply electronics for PID control of the lowest temperature stage thermometer with the supplied magnet current.

Stationary Equipment Support for holding dewar and system components

There must be a stand for the remote valve. (Please quote this as an optional separate line item)

There must be a stand to hold the ADR. (Please quote this as an optional separate line item)

Options

Vendor will supply an option for installation of measurement wiring per specifications of the customer.

Operation

Vendor will provide a description of typical recommended operation of system including estimate of total time to thermally cycle refrigerator to base temperature

Vendor will provide schematics of all components and manuals for all components including operation and troubleshooting

The system must include a thermometry system that monitors the temperature of the stages of the cryocooler, magnet, 1K stage, and base temperature stage. The readout of the base temperature stage must use a low-noise lock-in amplifier so that minimal excitation current is used to measure the temperature.

Performance Verification

After delivery of the system to GSFC, vendor will travel to GSFC to demonstrate operation of the system including meeting all specifications in this statement of work deemed relevant by the GSFC technical representative

At that time, vendor will also provide training to 2 GSFC employees and the technical representative on safe operation of the system.

Safety

All enclosed vacuum spaces will have pressure relief valves

Common electrical ground and emergency power off switch will be provided for electrical components

Vendor will install interlocks in the system where needed and describe whether these interlocks are hardware or software based. For example, the magnet current will remain zero until the magnet thermometer indicates that the magnet has gone superconducting.

Selection Criteria

The vendor will have a demonstrated record of delivering operational cryogen-free refrigeration units to customers. The refrigeration system must have a demonstrated record of being used to cooled superconducting transition-edge sensors. The vendor will supply a list of references for meeting the above requirements. NASA GSFC wants a system that best achieves or exceeds the requirements as written above.

Evidence of quality in manufacture or design for robust performance and longevity of system components

Best price for the specifications guaranteed by the vendor. We will assess vendors for the lowest price meeting the technical specifications. The vendor should indicate where better achievable specifications for the system can be acquired at a reasonable additional cost.

Speed of cooldown to base temperature

Availability of 1 year warranty for parts and service of cryogen free refrigeration system

Best schedule that incorporates the schedule requirements in this statement of work (see below) and presents a schedule that achieves milestones

Deliverables and Delivery Schedule:

Delivery of the system must be within 5 months of the date of award. The deliverables for this work are:

one (1) cryogen-free refrigeration system,
supporting electrical components to enable refrigeration (compressor for pulse tube cooler, magnet power supply for ADR)

supporting electronics for thermometry, heaters and other system components

hardware for mechanical support of the system or its components

Schedule:

2 weeks from date of award. Vendor presents design to GSFC technical representative for approval

2 months from date of award. Vendor informs GSFC technical representative of on site requirements for installation at GSFC; gives update on construction progress.

5 months from date of award. Vendor completes construction and delivers system to GSFC

6 months from date of award. Vendor demonstrates system performance at GSFC for final acceptance of system by GSFC technical representative.

Payment:

Vendor may invoice 50% upon approval of design by technical representative

Vendor may invoice 30% upon shipment of the system to GSFC

Vendor may invoice 20% upon technical acceptance at GSFC after system demonstration

Government Furnished Equipment:

For testing and acceptance at GSFC, lab space and supporting equipment (pumping station, leak checker, electrical power, cooling water, etc.) will be provided in accordance with requirements provided by the manufacturer.

Security:

none

Place of Performance:

Design, construction and assembly of the cryogen-free refrigeration system at the vendor location

Delivery and performance verification of the cryogen-free refrigeration system at NASA GSFC Code 553 laboratory

Period of Performance:

Anticipated period of performance for completion of all work is 6 months from date of award